Entry, Descent and Landing for Mars Sample Return

The European Technology Development and Demonstration Approach

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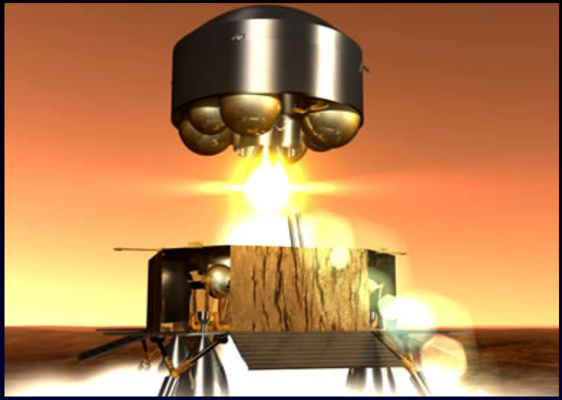
OUTLINE

- Mars Sample Return within exploration and in the Aurora Programme
- MSR: The mission and the entry, descent and landing approach
- The 'NEXT' mission opportunity and the preparation for MSR
- Descent and Landing technology development:
  - Tools & Testbeds
  - Guidance, Navigation and Control
  - On-board Navigation Systems
  - Landing system level development
- NEXT mission concepts and study approach
- Future of the NEXT mission
- Conclusions

MARS SAMPLE RETURN
Context

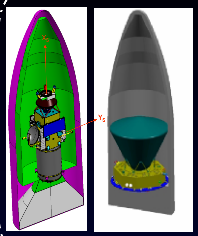


- Represents major step in Mars exploration in terms of:
  - achievement of long term science objectives, as identified by European, US and international science community
  - development of key enabling capabilities for future exploration including advanced robotic and possible human missions
- Foreseen in the 2020-2025 timeframe
- Internationally recognised as a key opportunity for cooperation

- Key milestone within Aurora Programme
  - Driver of key technologies and capabilities
  - Opportunity to develop expertise in critical fields: soft-landing, rendezvous, sample handling, planetary protection, robotics, bio-containment

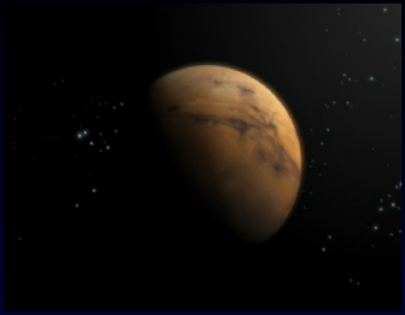
Internal Concurrent Design Facility (CDF) Study → 2 X Parallel Industrial Phase A1 Studies → 1 Phase A2 Study (Ongoing) – MSR + PreCursor

MARS SAMPLE RETURN Today



1st launch: *Orbiter+Earth Return Capsule*

2nd launch: *DM +MAV+ Carrier*



2 – Arrival at Mars – Orbiter & DM arrive separately

3 – Soft-Landing on Mars, with hazard avoidance

4 – Collection of samples (no mobility in phase A1; partial consideration in phase A2)

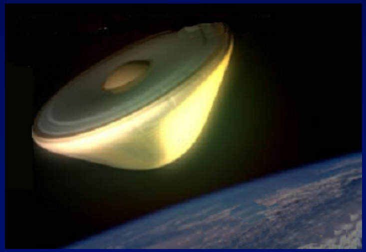
1 - 2 A5 ECA Launches

MSR Mission Scenario

5 - Ascent from the Mars surface

6 - Sample Transfer; current baseline is capture

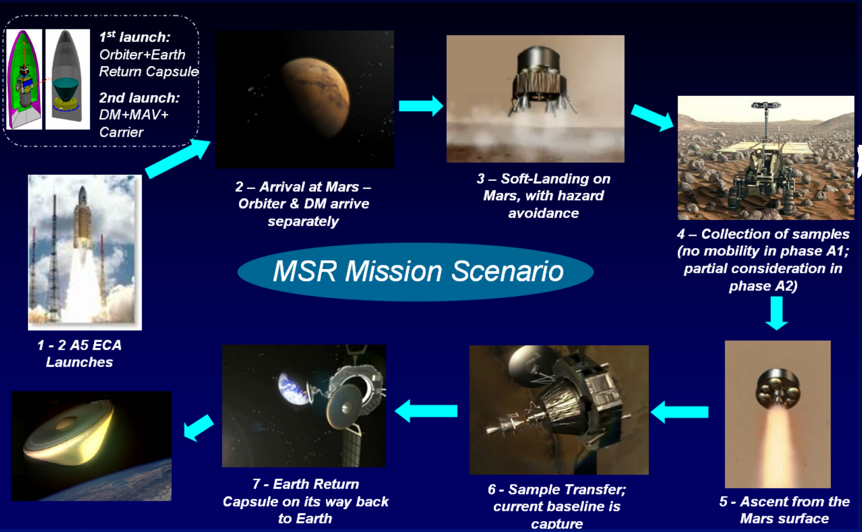
7 - Earth Return Capsule on its way back to Earth

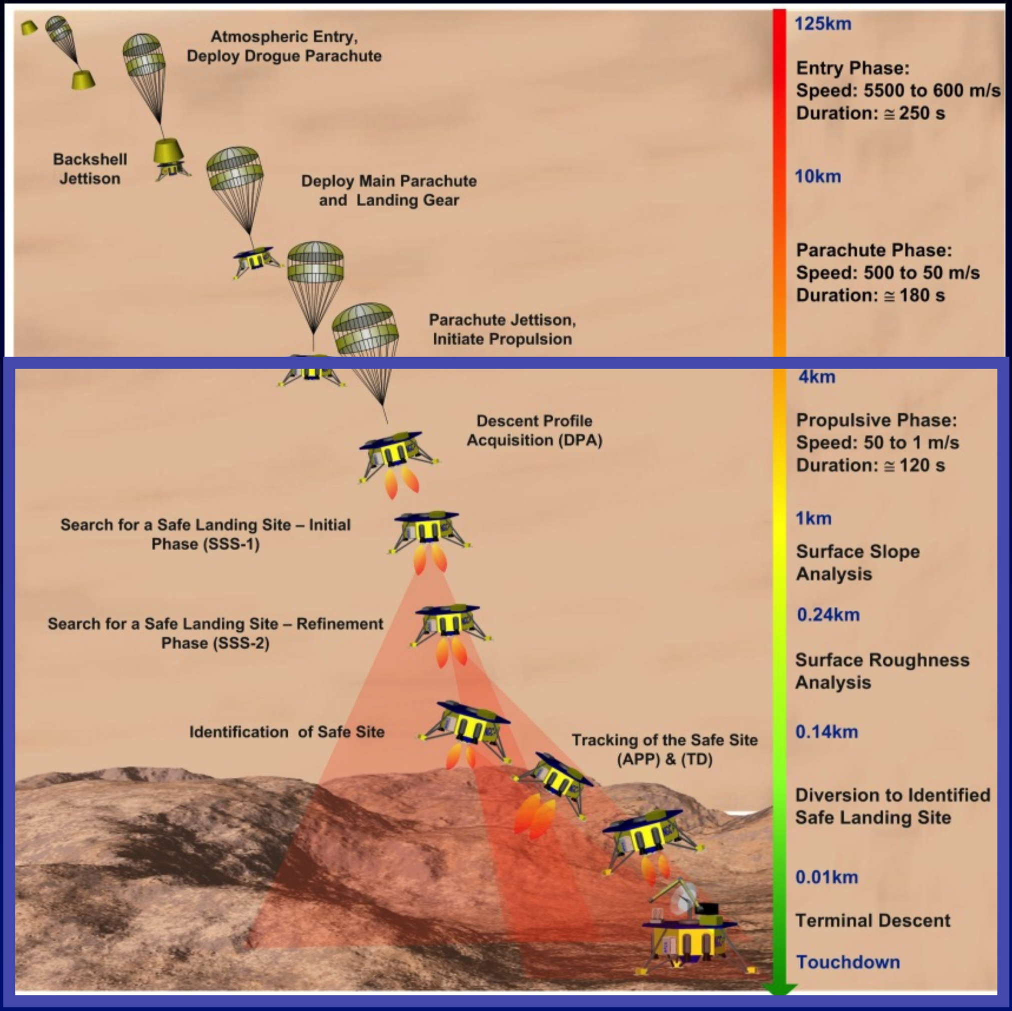


8 – High Speed Earth Re-Entry and Sample recovery

MARS SAMPLE RETURN
Today

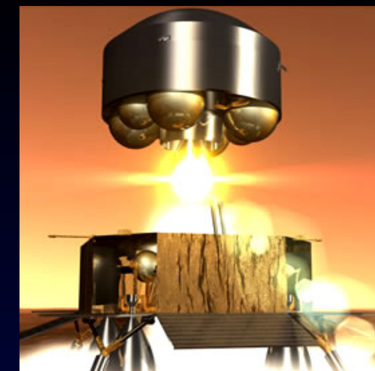
- MSR Mission studied up to Phase A2 level: ongoing
  - Revised mission architecture
  - Trade-off consolidation
  - Refinement of requirements definition





NEXT MISSION OPPORTUNITY

ESA EUROPEAN SPACE EXPLORATION PROGRAMME AURORA



NEXT Mission opportunity

2006 2008 2010 2012 2014 2016 2018 > 2020

NEXT mission proposal and approval – Ministerial Council 2008

Phase B | Phase C/D

Next Exploration Science and Technology Mission (NEXT)

→ Demonstration of key enabling capabilities for exploration

Soft Precision Landing

Autonomous Rendezvous

High Speed Earth Re-Entry

∴Required technologies must be at TRL 6 by beginning of Phase B, in 2009

i.e. system prototypes tested in a relevant environment (e.g. analogous earth based test sites)

→ Driving parameter in elaboration of technology development approach for NEXT missions

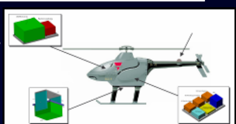
CONTEXT AND TIMING

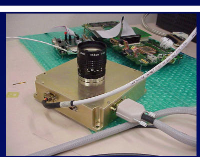
late 2008		2010		2012		2014		2016

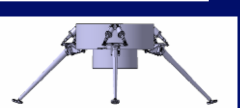
Ministerial Council

Phase B | Phase C/D* *approx indicative duration*

Required to have Soft-Precision Landing GNC elements at TRL 5-6,
i.e. demonstration in relevant environment, by mission Phase B

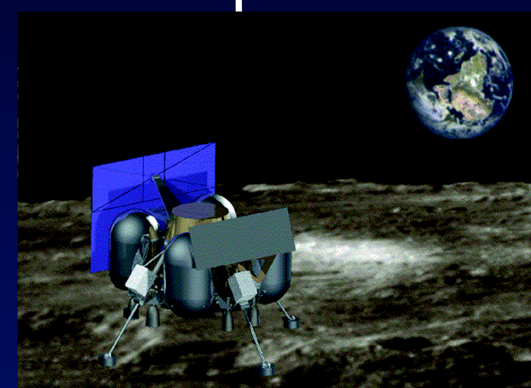






Autonomous Soft-Precision Landing System

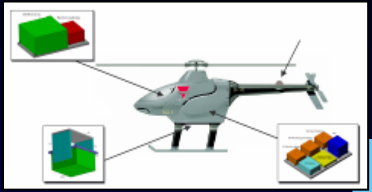
Integration at system level

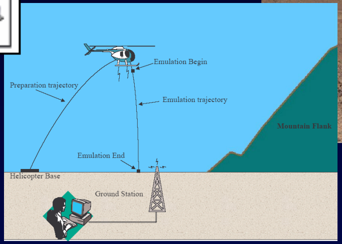


NEXT Mission –
demonstrating soft landing on Moon

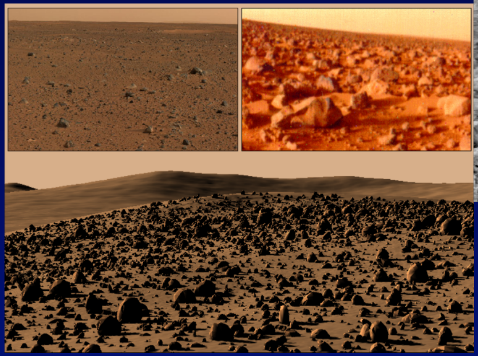
Tools and Earth-based Testbeds

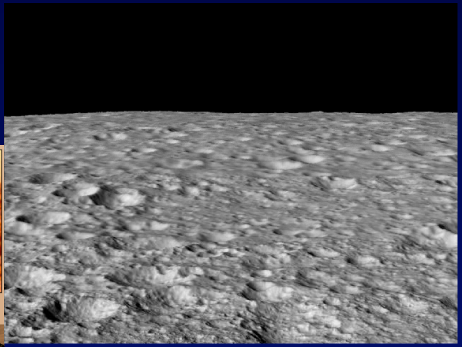
- Tools and on-ground test beds are required in order to verify the functionality, performance and operation of GNC components and integrated systems at various stages in their development
- Ongoing work to develop a dedicated Precision Landing GNC Test Facility (PLGTF):
  - Helicopter UAV
  - Navigation sensors in-the-loop
  - Gimballed platform





- High Fidelity End-to-End EDL Simulator which will enable performance testing and assist in EDL system trade-offs
- Terrain simulation tools: Planetary and Asteroid Scene Generation Utility (PANGU)
- Landing system level test-bed

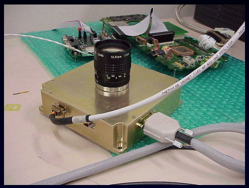




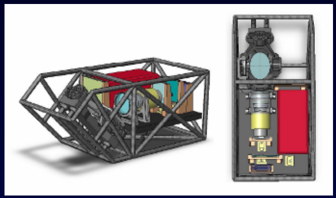
Simulations generated by PANGU: Referenced to University of Dundee

On-Board Navigation Systems

- On-board navigation represents the eyes of the spacecraft and its ability to process what it receives - this comprises:
  - Vision-based systems – e.g. *multi-purpose vision based navigation system, built upon NPAL heritage (from Bepi-Colombo project), for rendezvous and landing applications*



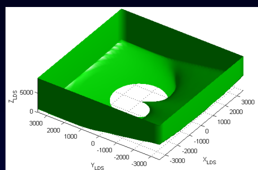
  - LIDAR-based systems – e.g. *preliminary development underway through parallel work with ABSL and Jena-Optronik*



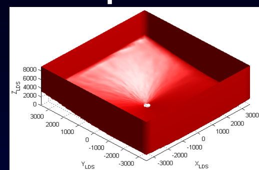
  - Vision and LIDAR based landing-navigation techniques, to make sense of the inputs received
  - Both vision and Lidar-based navigation technologies are considered in order to allow future mission flexibility, robustness and to investigate the different mass/power dependencies
- Heritage and experience already exists in Europe through:
  - Past work on autonomous vision & Lidar based navigation techniques
  - Vision-based sensor pre-development – *NPAL Camera hardware and algorithms*
  - LIDAR sensor development –*Parallel development of European LIDAR through ongoing ESA contract*
  - Currently, these various elements are developed up to TRL: 3-4 (with software aspects generally being a little more mature than the hardware elements)

System Development

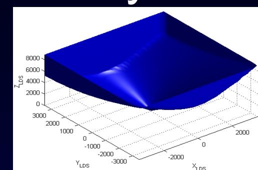
- The GNC system itself, excluding the navigation sensors, represents the integration and combination of the required hardware and software needed to make sense of the navigation inputs, determine the required action and give instructions to the respective control systems



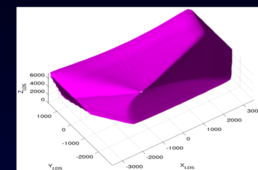
Fuel consumption



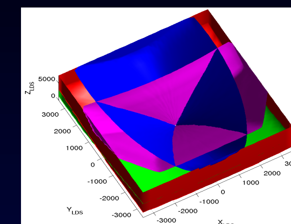
Trajectory constraints



Visibility constraints



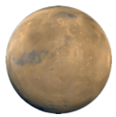
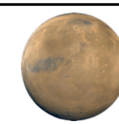
Thrusters constraints



- In addition to GNC, also crucial to the overall system development is the landing platform, i.e. landing legs, which should ensure the robustness of the system during final landing stages and also guarantee the platform's final position

- Substantial heritage and experience exists in Europe through:
  - Initial development of both Vision and LIDAR-based GNC systems (TRL: 2-3)
  - Ongoing work on landing legs which will culminate in single-leg testing (TRL: 3)
  - Assessment of Chemical Propulsion options to exploration missions
- Propulsion system development will be based on outcomes of NEXT mission studies – allow efficient targeting of available resources

NEXT MISSION PREPARATION

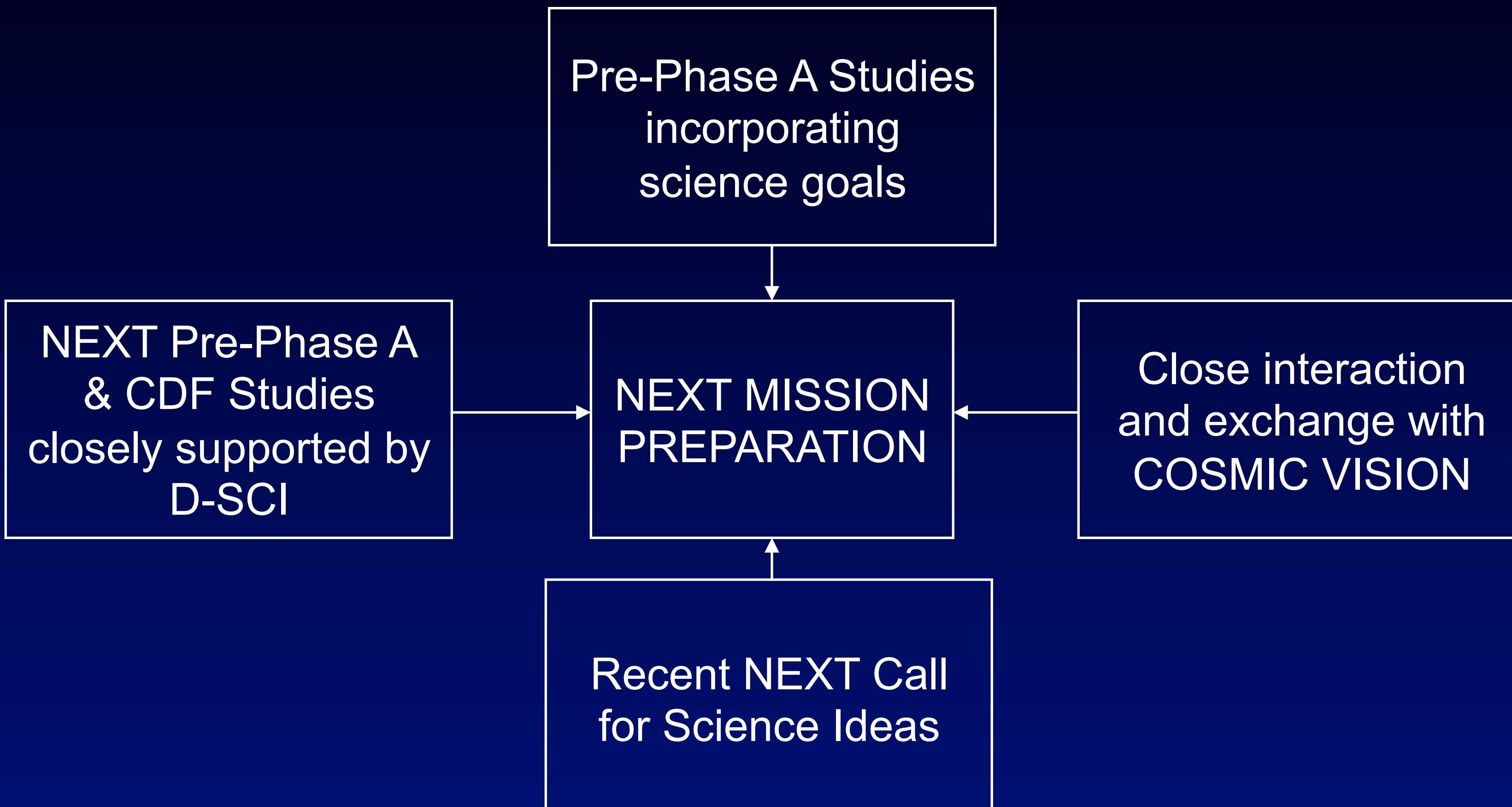
	M-1	M-2	M-3	M-4	MarsNEXT	Lunar Sample Return
Contractor	TAS-I	EADS-SAS	TAS-F	ASTRIUM-SAS	CDF	CDF
Target						
Launcher	Soyuz	Soyuz	Soyuz	Soyuz	Ariane-5 / Proton	Ariane-5 shared Proton
Main Demonstrated Technological Capabilities	1.Autonomous RdV and Capture	1. Soft Precision Landing (2. Hopping)	1. Autonomous RdV and Capture 2. Soft Precision Landing	1. Autonomous RdV 2. Soft Precision Landing	1.Autonomous RDV and Capture	1. Soft Precision Landing 2. Ascent 3. Earth Re-Entry)
Spacecraft	- Orbiter	- 1 Lander	- Orbiter - 1 Lander	- 2 Landers	- Orbiter	- Lander - Lunar Ascent Vehicle - Earth Return Capsule
Other Features	Surface Probe(s)				Surface Net-Science Probes	

PreCursor Mission & CDF Studies will be complete September 2007 → Phase A Study proposals to PB-HME → Initiation of NEXT Phase A Studies early 2008 → Proposal of NEXT Options to Ministerial Council of end-2008 – Approval of further phase of NEXT

NEXT – SCIENCE

Aurora Programme: Combination of exploration technology development and enabled/enabling science

Aurora Core Programme: Technology development for exploration



CONCLUSION

- Entry, descent and soft-precision landing with hazard avoidance is seen as a key capability for future exploration missions
- MSR represents the driver for many key capabilities including EDL
- Within the Aurora Core Programme ESA aims to focus effort on the maturation of NEXT mission concept(s), and thus the demonstration of key capabilities
- Technology developments will continue through the Core Programme, building on existing heritage and will be directly targeted at supporting the NEXT mission concept(s)
- Further Phase A studies of NEXT will be used as input to the Ministerial Council of 2008, to seek support for the future development of soft-landing in Europe and its first application in the NEXT mission

QUESTIONS ?

BACKUP

SOFT-PRECISION LANDING

Future missions foreseen to the Moon and Mars, both robotic and human, place several key requirements on EDL systems

- Soft – *in order to be able to land more massive and more sensitive payloads, which cannot survive current airbag based landings*

  Future exploration payloads are likely to be more massive, and more sensitive to landing forces and orientation than the payloads currently landed using airbags (e.g. small rovers)

SOFT-PRECISION LANDING

Future missions foreseen to the Moon and Mars, both robotic and human, place several key requirements on EDL systems

- Soft – *in order to be able to land more massive and more sensitive payloads, which cannot survive current airbag based landings*
- Precision – *in order to be able to target areas of specific exploration interest*

Many areas of interest for future exploration are more localised, e.g.
peaks of eternal light at edges of lunar polar craters,
possible water deposits within dark lunar craters,
specific geological formations on both Moon and Mars,
locations believed to be key for investigating life, past and present, on Mars

SOFT-PRECISION LANDING

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- Precision – *in order to be able to target areas of specific exploration interest*
- Hazard Avoidance – *in order to be able to avoid surface hazards and so reduce risk to payloads*

Locations of interest for future exploration missions are also often in areas containing potential hazards during landing e.g. large rock fields, crater edges, cliffs etc locations believed to be key for investigating life, past and present, on Mars

SOFT-PRECISION LANDING

Future missions foreseen to the Moon and Mars, both robotic and human, place several key requirements on EDL systems

- Soft – *in order to be able to land more massive and more sensitive payloads, which cannot survive current airbag based landings*
- Precision – *in order to be able to target areas of specific exploration interest*
- Hazard Avoidance – *in order to be able to avoid surface hazards and so reduce risk to payloads*
- Autonomy – *in order to perform all of the above as well as coping with unforeseen events, without relying on communication with ground*

Particularly at Mars, but also for the Moon, communication between a lander and Earth will be limited – this implies the system must be able to make decisions based on its environment and changes which might occur

SOFT-PRECISION LANDING

Future missions foreseen to the Moon and Mars, both robotic and human, place several key requirements on EDL systems

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Soft-Precision Landing represents the capability of satisfying the above requirements

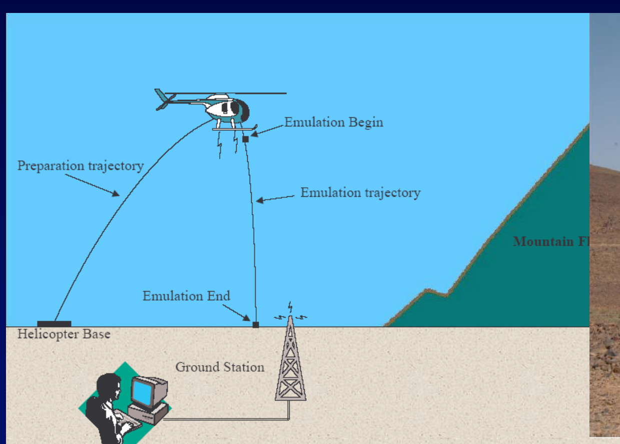
Main elements required for this capability include **Guidance Navigation and Control (GNC), touchdown system (i.e. legs, shock-absorbers) and propulsion**

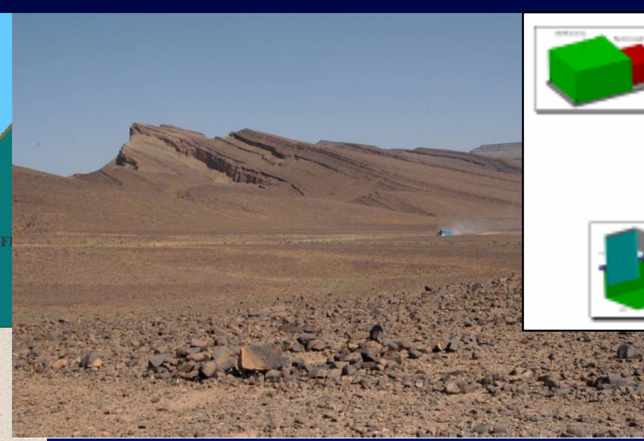
GNC and touchdown system are directly addressed in the following approach

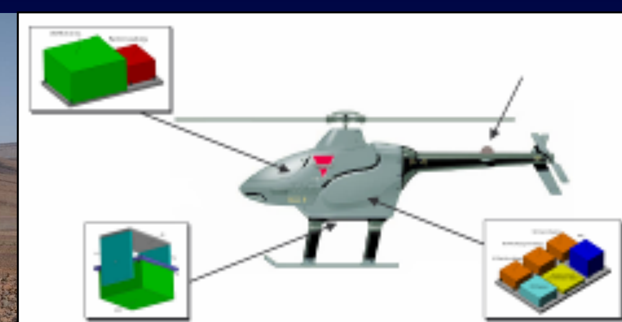
Propulsion is recognised as a critical element, identified through past Aurora activity – system outputs from PreCursor mission studies will be used to define a robust programme of technology development in the near future

Precision Landing GNC Test Facility

- The PLGTF is an autonomous helicopter based facility, currently under development through ESA contract and should be available by *???*
- can emulate a lander's (Moon/Mars) descent profile over specific altitude ranges
- will accommodate various navigation payloads already matured, and those to be developed in the activities presented in the following slides (e.g. vision-based navigation camera, LIDAR based navigation sensor)
- foreseen test site, in Morocco, will present representative terrain, i.e. hazards, topography, to fully assess navigation hardware and software performance
- *PLGTF Enhancement*, already approved in Core Programme, will upgrade facility to enable closed loop testing and provide even more representative conditions







- The PLGTF is a key element in the maturation of GNC technologies

ENTRY DESCENT AND LANDING

Entry, descent and landing (EDL) is certainly a key capability for exploration since it enables access to another planetary surface

Mastering EDL is therefore a critical first step to performing:

- in-situ scientific investigation of surfaces of the Moon & Mars
- landing hardware necessary to perform Moon or Mars sample return
- demonstrations of critical technology required for future exploration e.g. life support systems, in-situ resource utilisation

In the case of Mars landing, the full EDL sequence applies including the planetary entry

Absence of atmosphere implies differences for lunar landing, though many parts of the descent and landing are similar to Mars

Relation to ExoMars:

ExoMars landing will rely on airbag technology

Limitations on mass delivered to the surface

Landing loads still impose limitations on types and configurations of payloads which can be accommodated

ExoMars EDLS sequence not optimised for type of accuracy required in future exploration applications

Next step in EDLS capability required beyond ExoMars - <u>Soft Precision Landing</u>